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FLIGHT DATA SYSTEMS USING LSI P-CHANNEL MOSFETS

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For a number of years, we have carried out a research and development program concerned with the general improvement of space flight signal and data processing systems for experiments. We are concerned with components; linear circuitry; digital circuitry; and special effects due to noise suppression, radiation damage, and so on. For instance, as a result of our efforts, there is now available on the GSFC Preferred Parts List a line of very low power, complementary bipolar circuitry using hybrid thick-film techniques.

For the last two years, we have been helping to support the continuing development and expansion of a series of P-channel MOSFET circuits which had its beginnings in the IMP program. The GSFC engineers primarily responsible are Hosea White and Don Lokerson. The commercial manufacturer of these custom devices is American Micro-Systems Inc. (AMI).

The evolution of these circuits from discrete devices to the present LSI devices, or bugs, some of which have more than 1000 transistors on a chip, and the effects this advanced circuitry has had on experiment and spacecraft design are really astounding. Figure 1 tells a qualitative story using the IMP program as an example. Across the top of the figure, data flow is traced from the experiment sensors through the data system to the transmitter, function by function. Four spacecraft examples are shown with light gray denoting the experiment contribution or responsibility and dark gray denoting the spacecraft data system responsibility. The vertical extent in a given block is intended to indicate the relative functional complexity. Several features are to be noted:

(1) As one has learned more about what is going on in space, the sensor systems and their immediate electronics have become far more sophisticated and complex.

(2) On IMP I, a large increase in sophisticated analog processing was noted, as was a dramatic increase in the demands and abilities of the digital system.

(3) On IMP H and IMP J, more useful MOSFET bugs were available, and the spacecraft engineers were able to simplify the experiments even more.

(4) It is interesting to note that if we were to include the proposed IMP KK′ here, or Pioneer F and Pioneer G, or Helios A and Helios B experiments, for instance, the picture would change markedly. Much of the dark gray would be light gray because a sophisticated set of bugs or circuits is available. Experimenters can build their own sophisticated special purpose data system, and the spacecraft will revert back to central functions typical of IMP D and IMP E, for instance.

Figure 2 adds further detail to what I have been saying. Horizontally, years from 1960 to 1971 are plotted, and several satellite milestones are shown. The left ordinate gives the number of cans, flatpacs, or bugs in the data system and is to be used with the circular data points and the thin narrow curve. The right ordinate gives the number of semiconductor devices in the system and is to be used with the diamond-shaped data points and the heavy curve.

The can count increased rapidly at first, to approximately 1000 to 1500 devices, but has since decreased. The number of semiconductors has increased by more than three orders of magnitude. The IMP I data and encoding system has approximately 328,000 semiconductors, and IMP H will have approximately 500,000. In this time, there has been an evolution from discrete transistors to several transistors in a can to MSI to LSI. The spacecraft capability and complexity have increased markedly, but because of parallel data paths and the high reliability of these parts, the reliability is probably much higher. Currently, the IMP program has shown greater than 700×10^6 device-hours in orbit with an absolute maximum of 2 device failures.

Previously, I had referred to the next step in this evolution being experiments having their own extensive data systems. At least three experiments on Pioneer F and Pioneer G are using these devices, and we are also using them on Helios A and Helios B and expect to use them on HEAO.

For Helios, our experiment data system will use approximately 130 bugs and have a semiconductor count of greater than 100,000. It will weigh less than 1 N and use less than 1.2 W. This system probably will use more transistors than all the rest of the spacecraft combined.

Table 1 is a summary showing the size of the family available, the part numbers, and GSFC drawing numbers. In addition to funding the TREE and PHA bugs, an additional LSI bug is now being funded which will be called the Helios bug. Up to 12 bits can be entered, either serially or in parallel, and then shifted out. The availability of a family of low weight, very low power, very reliable parts that are also low cost (~$150 per bug with NASA specifications) is a major advance.

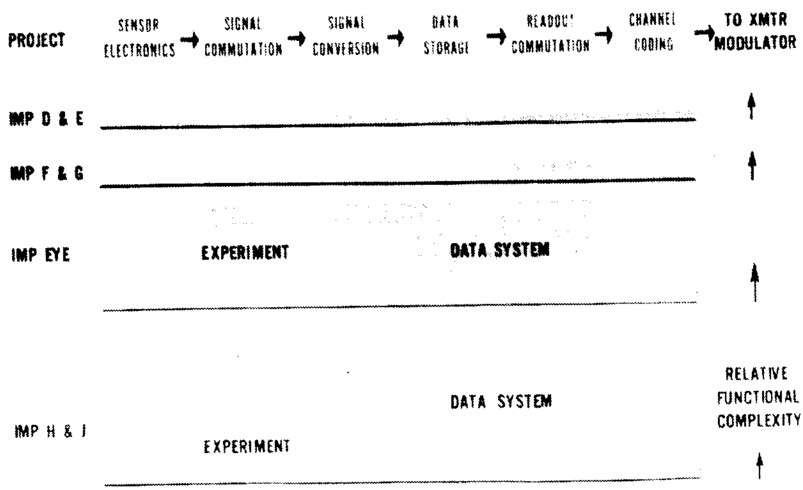

Figure 1—Spacecraft data flow.

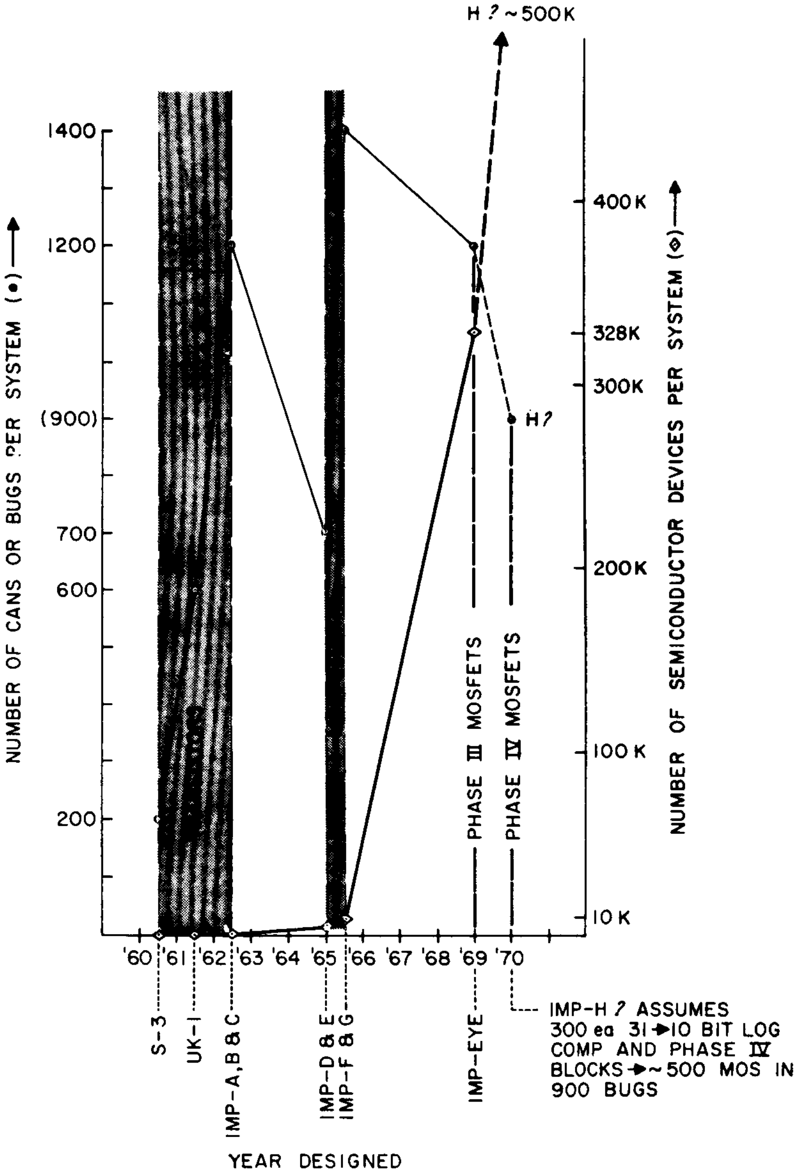

Figure 2—Evolution of encoding system.

Table 1 –MOSFET block part numbers and drawing numbers.

BLOCK NAME	AMI #	GSFC DRAWING #
	PHASE I BLOCKS	
Logic Block	SC-1128B	GD-1154-025 (2 sheets)
Logic Block	SC-1129B	
Logic Block	SC-1173B	
Binary Block	SC-1149B	
	PHASE III BLOCKS	
ATXC Floator Block	C-1275	G?-1154-042 (9 sheets)
ATX Registors Block	C-1276	
10 Channel Switch	S-1304	GD-1154-044
Universal 4 Bit MOS Commutator	S-1304	GD-1154-043
Outside World 4 Bit MOS Commutator	S-1307	GD-1154-048
	PHASE IV BLOCKS	
16 Bit SR with Storage	C-1308	GE-1281-452
MARS BUG	C-1375	GE-1154-047
TREE BUG	C-1487	GE-1281-454
PHA BUG	C-1652	GE-1281-455
HELIOS BUG	--	GE-1281-456